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THE CHOICE OF CROPS FOR SALINE LAND[1]

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INTRODUCTION

Salinity, an excess of readily soluble salts in the soil, is one of the most serious obstacles to agriculture in the arid portion of the United States. Irrigated land that has a high water table is most likely to suffer from salinity.

The history of agricultural development in the West contains numerous instances of irrigation projects which had promising beginnings in localities where land values have subsequently been much impaired by the appearance of salts in excessive quantity. It has been estimated that one-tenth of the irrigated land in the western part of the United States, or approximately 1,500,000 acres, contains an injurious quantity of salts. Some of the most valuable land in that part of the country, adapted at the outset to the best-paying crops and situated most advantageously with respect to towns and transportation lines, has become practically useless because of these salts.

The remedy unquestionably is to get rid of the excess of salts wherever possible by flooding and drainage. But it often happens that there are obstacles in the way of reclaiming such land. The individual farmer may not be able to obtain an outlet for his waste

[1] This circular is a revision of and supersedes Farmers' Bulletin 446, The Choice of Crops for Alkali Lands. The term "saline" is used instead of the term "alkali" because it more accurately describes the conditions.

[2] The writers are indebted to the Division of Forage Crops and Diseases for much valuable information concerning the salt tolerance of forage plants.

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water until a comprehensive drainage system has been established in his neighborhood. Climatic conditions or the distance from markets may prevent the growing of sufficiently profitable crops to warrant the cost of reclamation. Even where reclamation is feasible the process often requires several years, and meantime both the land and the farmer's income will benefit if some crop is put in at the earliest stage when a stand can be secured. Prolonged flooding of land which previously contained a large quantity of salts is apt to impair the texture of the soil, especially if a heavy one, causing it to become puddled. This will be avoided to some extent if crops are grown during the progress of reclamation.

The object of this circular is to bring to the attention of owners of saline land the crop plants which are most likely to give satisfactory results. It cannot be too emphatically stated that crop production on such soils is at best precarious. For this reason and because the tolerance of plants for salts depends upon many varying conditions, it is impossible to offer more than suggestions as to what crops are most worth trying.

CONSTITUENTS OF THE SALTS

The soluble salts that occur in toxic concentrations in soils in the western part of the United States represent various combinations of a limited number of constituents. In each of the ordinary simple salts there are two constituents or ions, one of which is basic, the cation, and the other acidic, the anion. For example, common table salt (sodium chloride) is a combination in definite proportions of the cation sodium with the anion chloride. The best evidence available indicates that in a water solution of such a salt the two constituents are dissociated and exist as independent ions. Furthermore, it is believed that the physiological effects of these salt constituents in solution are exerted by them in their ionic form rather than in their combined form as salts.

The characteristics of these constituents in their combined forms as salts are important in one respect, however, namely, solubility. For example, the limit of solubility in water of the sulphate ion (SO_4) as calcium sulphate is low, approximately 0.2 percent for the salt if the requisite quantity of calcium is present. On the other hand, if calcium is deficient and sodium or magnesium is present, the limit of solubility of the sulphate ion is very much higher.

The number of salt constituents that, because of their abundance, are of major importance in saline soils is usually not more than six or seven. These include the three cations calcium (Ca), magnesium (Mg), and sodium (Na), and the four anions carbonate (CO_3), bicarbonate (HCO_3), sulphate (SO_4), and chloride (Cl). There are some places where the nitrate (NO_3) anion occurs in concentrations similar to the others named, and boron in the form of one of the borate anions may also occur in concentrations that are toxic to some plants.

The relative proportions in which these constituents may occur is widely variable. In general, their proportions are much the same in any circumscribed area where the salinity has been derived from a common source. Their concentrations, both individual and collec-

tive, are also extremely variable. They vary not only from place to place in any area but from one position to another in a vertical section of the soil and from one time to another in the same area and soil section. Because they are soluble in water these salt constituents are readily transported by the movement of the water in which they are dissolved, and they remain in the soil or on its surface if the water evaporates.

SOURCES OF SALINITY

The major part of the dissolved salts that cause crop injury in arid regions come from exposed rock material of the earth's crust, from which they are liberated during the weathering and decomposition involved in soil formation. The same kinds of rocks and the same weathering processes occur in both humid and arid climates. In humid climates most of the soluble products of soil formation are leached from the soil by rain water and transported ultimately to the oceans. In arid regions, however, while the rainfall may be adequate for local leaching, the soluble salts are not often carried very far and may accumulate in low spots where the water collects and evaporates. In addition to the salts that come directly from rock decomposition there is another source in the exposed or superficial deposits of sedimentary material that have been laid down during earlier geological periods in saline or brackish waters. The erosion by rain waters of these sedimentary deposits may yield large quantities of soluble salts to the country drainage. Still another but less important and more local source of salinity lies deep in the earth's crust where some salt constituents, such as carbon dioxide, chlorine, and boron, occur in gaseous form, usually mixed with hot water vapor. These gases reach the surface through fissures in the rock or through fumaroles. They may escape directly into the atmosphere to return to the earth with rain or they may encounter superficial circulating ground waters in which they dissolve and appear in mineral springs, often as hot springs.

Soluble salt may occur in excessive quantities as a natural constituent of arable and irrigable desert lands. Its presence may be indicated by the absence of vegetation or by the nature of the vegetation if any. It may also be determined by testing the soil. The experience of pioneers has shown that attempts to utilize naturally saline soils for crop production under irrigation are expensive and hazardous and often are finally unsuccessful. Because of this and also because, in the arid regions of this country, the area of nonsaline and potentially productive soil is usually in excess of the available supplies of irrigation water, the problems and methods of reclaiming the naturally saline soils have not been the most pressing aspect of the salinity problem. These saline soils are now regarded as belonging with rough, sandy, or rocky areas and as not suitable for irrigation.

The chief concern in respect to salinity in irrigated soils arises when it becomes apparent that crop injury on land that was formerly productive is resulting from the accumulation of soluble salts in the soil solution. These salts are contained in the irrigation water and become concentrated in the soil solution as the water evaporates from the soil or is absorbed and transpired by plants. Usually these

evidences of crop injury from salt appear at first in isolated spots in the fields, but in time the spots increase in size and the evidences of crop injury become general. The prevention or remedy of salt injury lies in the more copious use of irrigation water accompanied, when necessary, with drainage that will remove the soluble salts from the soil instead of permitting them to accumulate.

THE SOIL SOLUTION

The water required by crop plants for their growth processes is absorbed through their roots from the solution held in that portion of the soil occupied by the roots and known as the root zone. Many crop plants absorb and transpire as much as 500 pounds or more of water for each pound of dry matter produced by growth. In humid regions the water of the soil solution is replenished by rain which contains very little dissolved material. In arid regions where the soil solution must be replenished by irrigation the water added always contains appreciable quantities of dissolved salts, and sometimes the quantities are large. Consequently, the soil solution of irrigated land is characteristically more saline than that of nonirrigated cropland.

The salt constituents added to the soil solution with each application of irrigation water tend to increase the concentration of that solution because some of the water is dissipated by direct evaporation from the soil and also because the plants usually absorb water from the solution without absorbing in corresponding quantities the dissolved salt constituents. Consequently, the effect of both direct evaporation and plant absorption is to leave the soil solution more concentrated as its volume decreases. There are two processes that tend to retard the rate of concentration of the soil solution in the root zone. One of these operates through the natural precipitation of a salt from the solution when the concentrations of its two constituents reach the limit of its solubility. Thus when the concentrations of calcium (Ca) and of sulphate (SO_4) reach the limit of solubility of the salt calcium sulphate ($CaSO_4$) at approximately 0.2 percent, that salt is precipitated from the solution and becomes a part of the soil. The other process operates through the natural displacement of the soil solution of the root zone, which occurs when the quantity of water added to the soil, by irrigation or by rainfall, exceeds the water-holding capacity of the soil. This process is known as leaching.

The concentration of the dissolved constituents of the soil solution at any time and at any place is the resultant of the operation of these two limiting processes, opposing the natural increase that would follow from the continuing addition of these constituents with each irrigation. In any one place the concentration of the solution is almost constantly changing. It is diluted by rain or by irrigation and concentrated by evaporation or plant absorption. Immediately after a rain or an irrigation it may be more dilute near the ground surface than it is in the deeper part of the root zone, while after a period of drought it may be more concentrated at or near the surface of the ground. In general the concentration of the soil solution in an irrigated field is higher than that of the irrigation water. Sometimes it is six or eight times as high.

EFFECTS OF SALT CONSTITUENTS

The effects of the dissolved constituents of the soil solution are manifested in two ways. One is directly on the plants, and the other is on the physical condition of the soil, with subsequent or indirect effects on the plants. Of these two the nature of the direct effects on plants is not so well understood as is the effect on the soil. It is well known that when certain of these constituents occur in the soil solution at or above certain concentrations, the normal processes of plant growth are impaired or inhibited. It is not so well known how these growth processes are deranged, whether by retarding water absorption and its translocation within the plant or by some other disturbance of the vital processes. It seems probable that one constituent affects the plant in one way and another in a different way. It is known that some constituents are, in lower concentrations, not only harmless to plants but actually beneficial or even essential, while in higher concentrations these same constituents are injurious or poisonous.

It is also known that the different species of crop plants react very differently to the several salt constituents. Some plants tolerate or even thrive in the presence of concentrations of a dissolved constituent that are injurious or even fatal to plants of other species. It is probably not true, however, that plants differ in this way in respect to all of the common salt constituents. That is to say, two plants may differ greatly in their tolerance to one constituent and differ much less in respect of another. Not very much information is available as to the influence in plant reactions of one constituent on another, whether the effect of one is influenced by the presence or the concentration of another. It is known that any given plant may be much more liable to injury by a given concentration of a constituent at one stage of its growth than at another stage. In general, plants are more susceptible to injury in the seedling stage than later.

The reactions that occur between the soil and certain of the dissolved constituents of the soil solution have a profound effect on the physical condition of the soil and ultimately on the well-being of the crop plant. These reactions involve only the basic or cation constituents of the soil solution, chiefly the calcium, magnesium, and sodium. Constituents of this kind occur in the soil in combination with the soil particles. When the soil is in contact with a water solution, exchange reactions take place in the direction of a condition of equilibrium between the soil and the solution in respect to these constituents. As the nature of the solution is changed by the addition of the dissolved constituents brought in by the irrigation water, reactions of base exchange take place. If the basic constituents added by the irrigation water are chiefly calcium and magnesium, these ions combine with the soil, and as a result the soil becomes more friable and permeable to water. On the other hand, if sodium is the chief basic constituent of the irrigation water, the trend of base-exchange reactions is in the direction of increasing the combined-sodium content of the soil, with the result that the soil becomes deflocculated and impermeable to water. As this condition develops it becomes increasingly difficult to replenish the water supply of the root zone by

irrigation and also more difficult to establish a condition of surface tilth favorable for a seedbed.

It is necessary, then, to an understanding of the effects of salinity in soils in relation to crop production to keep in mind these two aspects of the problem. Each is important and may be decisive. In choosing crop plants to be grown on saline soil it is not enough to consider only their tolerance to conditions of high salinity in the soil solution; it may be necessary to consider also their tolerance to the adverse physical conditions of the soil that are often associated with those cases of high salinity in which the salts of sodium are dominant.

CULTURAL AND IRRIGATION METHODS

Success in the use of saline soils for the production of crops depends quite as much on good farming as on the proper choice of crops. The natural conditions in saline areas are usually unfavorable to plant growth so that it is necessary to use the best possible methods of tillage preparation and of irrigation to improve these conditions. In the first place the land should be leveled very carefully to insure its being irrigated uniformly and there being no low places in which the water can remain after irrigation. The importance of this preliminary work cannot be overemphasized. Then the best possible condition of tilth for a seedbed should be established. After seeding, the surface soil should be kept moist if necessary by frequent light irrigations, to favor prompt and uniform germination. Subsequently irrigation should be applied as frequently as is possible without injuring the growing crops.

In view of the fact that in saline soils the soil solution is too concentrated and also that in the seedling stage the plants are more susceptible to salt injury, it should be the aim, when possible, to seed the crop when the solution in the upper part of the root zone has become diluted with rain water. In any event the surface soil should not be allowed to dry out after seeding, at least not until the plants are well started. It is also desirable to do what plowing may be necessary well in advance of seeding time and, if there are no rains, to irrigate the land several times before seeding. This will displace the concentrated soil solution from the upper soil where the seeds are to germinate. A good plan is to prepare the land carefully some months before seeding time, then spread farm manure on the surface and disk it in lightly, irrigate several times, and harrow after each irrigation as soon as the surface soil is dry enough. When the best possible condition of surface tilth is obtained, put in the seed and keep the surface soil moist until the crop is up.

It will be understood that the cultural methods here recommended involve the uniform surface irrigation of the soil by flooding in basins or checks rather than using furrows. When irrigation water is applied through furrows, only a part of the surface soil is wetted from above. The movement of water into the ridges between the furrows is in a lateral direction, and consequently the dissolved salt in the surface soil is not carried downward as it should be.

In some situations the immediate aim or need may be to produce a crop on saline soil without attempting to remove any of the

excess salt. When this appears to be justified it is possible to use, with certain intertilled crops such as sorghum or cotton, a system of furrow irrigation. In such a case deep furrows may be made about 4 feet apart, and after two or more irrigations through these furrows the seed may be planted in the bottom of the furrow. Under such treatment the excess salt will be leached away from the vicinity of the furrow bottom and be largely deposited in the soil of the beds between the furrows. Repeated and copious irrigation after planting may leach out a limited area of root zone and permit crop growth even though the salt content of the adjacent soil remains high.

In places where crystallized salts are deposited on the ground surface or in a crust of the surface soil attempts are sometimes made to remove the salt by flooding the area quickly and draining off the floodwater. The object of the operation is to dissolve the salt and carry it off the field. As a matter of fact this method of salt removal is seldom effective. Experience, supported by field observations, has shown that the major part of the salt thus dissolved by the floodwater is carried down into the soil rather than off the field. In general the aim of the cultural and irrigation operations on a field of saline soil should be to leach the salt down through the root zone into the deeper subsoil or out through subsurface drains.

PURPOSE FOR WHICH THE CROP IS GROWN

Because a plant can grow in the presence of a given quantity and combination of salts it does not necessarily follow that it will be a successful crop under such conditions. The effect upon the product for which the crop is grown must also be considered. Wheat plants can make a good growth in the presence of a quantity of salts that will not permit the formation of well-filled heads of plump grain. Various kinds of fruit trees can endure a concentration that seriously injures the texture, sweetness, flavor, and keeping quality of the fruit. The burning quality of tobacco, the length and fineness of cotton fiber, and the purity coefficient of sugarcane and sugar beets may be impaired by a quantity of salts that is too small to interfere seriously with the growth of the plants. On the other hand, in such forage plants as are grown chiefly for a large production of stems and leaves, the actual salt tolerance of the plants as shown by their vegetative growth measures, within limits, the possibility of crop production on saline land. It has been observed, however, that when salts are present in large quantities some plants may take up so much from the soil as to render the forage unpalatable or even injurious to livestock.

CROP PLANTS ADAPTED TO DIFFERENT DEGREES OF SALINITY

The following salinity classifications are based upon the percentage of soluble salts by weight in a given depth of the soil. In referring to the different classifications when discussing the tolerance of any particular crop plant, it is assumed that the depth of soil is that ordinarily occupied by the roots of the plant in question.

Classification of Salinity

[Proportion of soluble salts to total dry weight of the depth of soil reached by the roots]

Designation:[8]	Percent
Excessive	More than 1.5
Very strong	1.0–1.5
Strong	0.8–1.0
Medium strong	0.6–0.8
Medium	0.4–0.6
Weak	0.1–0.4
Negligible	Less than 0.1

[8] These terms are used in order to avoid a constant repetition of figures of percentages in discussing the salt tolerance of crop plants.

It is the concentration of the soil solution within reach of the roots and not the total quantity of salts present in the soil which determines the effect upon plant growth. But as the soil moisture and hence the strength of the solution are extremely variable, saline lands can be classified only on the basis of percentages of the salts to the dry weight of the soil. In using the above classification in discussing the tolerance of plants, it is assumed that the soil contains a degree of moisture favorable for the growth of the crop in question; also, that the soil is not extremely sandy, for sandy soils hold much less water than loams or clays, and hence a given percentage of salts produces a more concentrated solution in very light soils.

The limits given are those for crop production; they take into consideration such matters as quality of the grain in cereals, of the fiber in cotton, and sugar content in sugar beets. The term "good crop" implies an approach to the normal production in nonsaline soils, while "fair crop" implies a product giving a reasonable return on the investment, the relatively low value of the land being considered. The limits as given apply to the maturing crop. For germination and growth during the seedling stage the limits will in many cases be considerably lower.

It should be understood that any classification of crops on the basis of their salt tolerance can be applicable only in a very general way, owing to the varying nature of the conditions (discussed in the preceding sections of this bulletin) which determine the effects of salts in any particular locality or soil. The classification applies most closely where the predominant salts are sulphates. In localities where common salt (sodium chloride) forms the bulk of the soluble material it will be found that most of the crop plants mentioned succeed best at the lower limits of the respective grades. If an appreciable quantity of sodium carbonate, constituting the so-called "black alkali", is present, the classification will not hold good at all.

In spite of these limitations, it is believed that the following grouping will be useful as a guide to the selection of crops for testing in saline soils, since the comparative tolerance of the different plants is sufficiently indicated. Further details regarding the tolerance of each crop are given under "Salt tolerance of various crop plants" (pp. 13 to 24).

EXCESSIVE SALINITY

Only a very few useful plants can be depended upon to grow where more than 1.5 percent of the dry weight of the soil consists of

soluble salts. Chief among these are the native and foreign saltbushes and related plants of the goosefoot family (Chenopodiaceae), which are of some value as forage. Certain native grasses, notably desert saltgrass (*Distichlis stricta*), which affords pasturage of inferior quality, can endure more than 1.5 percent. Sugar-beet plants can grow in the presence of as much as 2.5 percent, but the roots produced are small, the sugar content low, and the ash content of the juice too high. Among fruit trees the date palm is the only species that is at all likely to succeed.

VERY STRONG SALINITY

Where there is not more than 1.5 percent of salts in the soil, if other conditions are exceptionally favorable, sugar beets may give a fair crop, although they are not to be recommended for soils containing this quantity of salts. The date palm is still the only fruit tree which can be expected to yield fruit of good quality. Pomegranate bushes will grow, but will probably not yield edible fruit.

STRONG SALINITY

Under otherwise favorable conditions the following plants may be expected to yield fair crops in soils holding not more than 1 percent of salts: Sugar beets, mangels, strawberry clover (*Trifolium fragiferum*), western wheatgrass (*Agropyron smithii*), Rhodes grass (*Chloris gayana*), Bermuda grass (*Cynodon dactylon*), smooth bromegrass (*Bromus inermis*), and tall oatgrass (*Arrhenatherum elatius*).

MEDIUM-STRONG SALINITY

In soils that contain not more than 0.8 percent of salts, good crops of the following meadow and pasture grasses may be grown in addition to those mentioned in the preceding paragraph: Slender wheatgrass (*Agropyron pauciflorum*), crested wheatgrass (*Agropyron cristatum*), Italian ryegrass (*Lolium multiflorum*), and meadow fescue (*Festuca elatior*). Fair crops of rape, kale, sorgo, and barley hay may be grown.

MEDIUM SALINITY

The following plants should give good crops in soils containing not more than 0.6 percent of salts: Sorgo, foxtail millet, rape, kale, barley, rye, cotton, and asparagus. It is also possible to raise fair crops of milo, kafir, proso or broomcorn millet, wheat, oats, emmer, alfalfa, field peas, sweetclover, vetches, and flax. Among orchard crops, pears and possibly figs may be grown if other conditions are favorable.

WEAK SALINITY

Where the soil contains not more than 0.4 percent of salts, good crops of nearly all forage plants may be expected and good crops of all of the cereals except corn. Among truck crops, the beet, cabbage, cauliflower, celery, eggplant, kale, spinach, potato, sweetpotato, and tomato are the most likely to succeed. Grapes of the European type (vinifera) can be produced if other conditions are favorable.

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NEGLIGIBLE SALINITY

Practically all field-crop plants can be expected to produce profitably in the presence of less than 0.1 percent of salts if other conditions are favorable. Few of the truck and orchard crops are likely to suffer.

As previously stated, however, the limits for all of these crops will be lower if the salts are largely accumulated near the surface of the soil, especially at the time of seeding. Moreover, less salinity can be endured if the soil is very sandy or if an appreciable quantity of sodium carbonate is present. The existence of other unfavorable conditions, such as a deficiency of necessary plant-food elements in the soil, diseases, and, in the case of trees and other deep-rooted plants, a high water table, may lower the limit of tolerance below what it would be if salinity were the only injurious factor.

In the following list are given the crop plants which are most likely to succeed on land of different degrees of salinity. Only such plants as may be expected to give at least a fair crop in the absence of the unfavorable conditions mentioned in the preceding paragraph are included under each classification.

CROP PLANTS WHICH ARE MOST LIKELY TO SUCCEED IN THE PRESENCE OF DIFFERENT DEGREES OF SALINITY

- **Weak salinity (0.1 to 0.4 percent)**
  - Sweetclover
  - Cotton
  - Asparagus
  - Foxtail millet
  - Wheat (hay crop)
  - Oats (hay crop)
  - Barley (grain crop)
  - Rye (grain crop)
  - Rice
  - Sunflower
- **Medium salinity (0.4 to 0.6 percent)**
  - Slender wheatgrass
  - Crested wheatgrass
  - Italian ryegrass
  - Meadow fescue
  - Rape
  - Kale
  - Sorgo
  - Barley (hay crop)
- **Medium-strong salinity (0.6 to 0.8 percent)**
  - Wheat (grain crop)
  - Emmer (grain crop)
  - Oats (grain crop)
  - Grain sorghums
  - Proso
  - Alfalfa
  - Vetch
  - Horsebean
  - Field peas
  - Red clover
- **Strong salinity (0.8 to 1.0 percent)**
  - Sugar beets
  - Mangels
  - Strawberry clover
  - Rhodes grass
  - Bermuda grass
  - Bluestem (western wheatgrass)
  - Smooth bromegrass
  - Tall oatgrass

CONSIDERATIONS GOVERNING CHOICE OF CROPS FOR SALINE LAND

The owner of saline land who wishes to select crop plants for trial from the preceding list should first make a careful study of his situation, finding out all he can about the quantity of salts present in his land, the height of the water table, and the opportunities for drainage and for washing out the salts, at least from the surface soil. He should also take into consideration the climate of his locality, which necessarily limits the number of available crops, and the local marketing conditions, which determine what crops can be profitably disposed of.

If it should prove practicable to reclaim the land by flooding and drainage, the question will arise, What crops can be grown to best advantage during the progress of the work? If the soil is in poor physical condition or is deficient in humus or nitrogen, salt-tolerant green-manure crops should be tried whether or not the land is to be reclaimed by drainage. If immediate reclamation is not feasible, crops and tillage methods should be preferred which help to check evaporation and prevent the further accumulation of salts in the topsoil. If the water table is high and drainage is impracticable, shallow-rooted plants should be selected.

The following paragraphs contain suggestions as to the crop plants best adapted to these different conditions.

CLIMATIC LIMITATIONS

Many salt-tolerant plants, such as cotton, rice, and the date palm, can be grown only in the warmer part of the country. Climate also plays an important part in deciding the choice of crop plants for saline land in the Pacific Coast States, where the winter is mild and most of the rainfall occurs at that season. This allows certain crops to be grown on land containing too much salt to permit success with the same crops in summer. The cereals—barley, wheat, etc.—often give good results under these conditions, especially when grown for hay. Various leguminous forage plants (for example, vetches and horsebeans) can also be recommended as winter crops for moderately saline land in the States mentioned. Similar results can doubtless be obtained in Arizona and adjacent sections of low rainfall, provided sufficient water is available for frequent irrigation in winter.

FORAGE PLANTS

It has been pointed out that many plants can tolerate a quantity of salts which impairs the products for which they are grown to such a degree as to render them worthless as crops. On the other hand, the majority of forage plants, being grown chiefly for their leaves and stems, are successful crops wherever the plants themselves can make a good growth, provided, however, the quantity of salts taken up from the soil by the plants is not so great as to make the forage unpalatable. Various meadow and pasture grasses, strawberry clover, sorgo, foxtail millet, and rape are among the most satisfactory crops for land containing more than 0.5 percent and less than 1 percent of salts, while such leguminous forage plants

as sweetclover, alfalfa, vetches, and field peas may be expected to succeed in the presence of any quantity less than 0.5 percent when a stand is once obtained.

RECLAMATION CROPS

Such crop plants should be selected as can best endure the frequent floodings given saline land that is being reclaimed. Sorgo and strawberry clover are well adapted to these conditions. Rice is extensively used in Egypt as a reclamation crop and can be recommended for localities in the United States that have a suitable climate and an ample water supply. When the reclamation is approaching completion it is the custom in Egypt to seed the land to the clover known as berseem (*Trifolium alexandrinum*), and if a good stand is obtained the soil is considered sufficiently free from salts for the growing of cotton, the principal crop of that country. As berseem succeeds well only as a winter crop in regions that are almost free from frost, its usefulness in the United States will necessarily be very restricted.

The idea is current in some localities that saline land can be reclaimed merely by growing certain tolerant plants, such as saltbushes and sugar beets. As a matter of fact, the plants mentioned, when grown on saline soils, do take up considerable quantities of salts, as is shown by chemical analysis of their ash. The salts absorbed are, of course, removed from the land if the crop itself is removed. Yet the quantity of salts taken out by the plants is usually so small in proportion to the total amount in the soil that it is very doubtful whether land containing any considerable quantity of salts could be permanently reclaimed by the removal of many successive crops.

GREEN-MANURE CROPS

Saline soils are apt to be deficient in humus, and, especially if sodium carbonate is present, they tend to become puddled when wet and to form a hard, baked surface when dry, offering much resistance to the penetration of water. The tilth of such land can often be improved by disking in barnyard manure or plowing under a green-manure crop, where such a crop can be grown. The effect of thus incorporating organic matter is to loosen the surface, making it easier for water to penetrate the soil and to wash the salts downward. Furthermore, the loose material acts as a mulch, checking evaporation and hence retarding the return of the salts to the surface. It is also probable that conditions more favorable to the accumulation of nitrogen can be established by increasing the supply of organic matter.

The crop plants suitable for green manure which are most likely to succeed where there is more than 0.5 percent of salts are sorgo, barley, rape, and kale. Where there is not more than 0.5 percent of salts, foxtail millet, oats, barley, rye, and certain leguminous plants—alfalfa, sweetclover, field peas, vetches, and horsebeans—are likely to give good results if a stand can be established. Where they can be grown, leguminous plants are preferable, because they produce an immediate increase in the supply of nitrogen.

CROPS FOR SALINE LAND NOT BEING RECLAIMED

Other things being equal, those crop plants should be selected which leave the land in the best condition for succeeding crops. This depends upon the character of the plant itself and the cultural methods used in growing it. Thus, alfalfa, if a stand can be obtained, will shade the ground, reducing evaporation, and thereby help to prevent the salts from accumulating at the surface of the soil. On the other hand, the small grains (wheat, barley, oats, etc.) are less efficient in this respect, and unless the stubble is disked or plowed immediately after harvest and a soil mulch established, the intense evaporation from the hardened, unshaded surface will result in an accumulation of the salts in the topsoil.

Intertilled crops, such as sugar beets and cotton, are desirable for land containing a medium quantity of salts, provided a cultivation is given promptly after every rainfall or irrigation in order to check evaporation and thus prevent the return of the salts to the surface. It may even be advantageous on saline land to seed with a drill and to leave enough space between the rows to permit cultivation.

On land too saline for crop production by ordinary methods, a stand can sometimes be obtained by planting the seed at the bottom of furrows and running water through the furrows at frequent intervals. This method has been successfully used with sorghum in the Southwest. It has the effect of washing down what salts are present at the bottoms of the furrows, but meanwhile the soil between them is subirrigated and the salts accumulate at the summits of the ridges. The same thing happens when orchards on saline land are furrow irrigated. The result in both cases is that ultimately the condition of the topsoil is aggravated unless the land is occasionally leveled and heavily flooded in order to wash down the surface accumulation of salts.

CROPS FOR SALINE LAND HAVING A HIGH WATER TABLE

Shallow-rooted plants should be selected for land having a high water table. In many cases the best use that can be made of such land is to convert it into permanent meadow or pasture, the grasses being relatively shallow-rooted plants and also somewhat tolerant of salts. In addition to the native grasses which often occur naturally on such land, most of the cultivated grasses, strawberry clover, and sweetclover are well adapted to this purpose. As catch crops for land of this character when only a moderate quantity of salts is present, the small grains (barley, rye, oats, and wheat) will give at least a hay crop, especially in years of heavy rainfall.

SALT TOLERANCE OF VARIOUS CROP PLANTS

In the following pages many of the crop plants grown in the Western States are discussed in connection with their behavior on saline soils, the plants being arranged under the crop classes—forage plants, cereals, etc.—to which they belong instead of strictly in the order of their relative tolerance of salinity.

FORAGE PLANTS

As a rule, forage plants are likely to give the most satisfactory results on saline land, and among them hay and pasture plants which are grown principally for their stems and leaves are to be preferred to such plants as kafir, milo, and proso, in which seed production is an important feature.

In many parts of the West, barley, oats, and even wheat are extensively grown as hay crops, but to avoid repetition the relations of these plants to salinity will be discussed under the heading "Cereals."

MEADOW AND PASTURE GRASSES

No class of cultivated plants can be more safely recommended for saline land than certain meadow and pasture grasses. Subirrigated lands in valley bottoms that carry considerable salts can be utilized in no better way than as permanent grass meadows and pastures. Bluestem (western wheatgrass) grows wild in many parts of the western United States, where it is highly esteemed for hay and pasturage. It is frequently found occurring naturally on saline land, and in field experiments it has proved to be very tolerant of salts. This plant can make some growth in the presence of 2 percent of salts in the first 2 feet of the soil, and seed can be ripened in the presence of 1 percent. Where the salinity is only medium strong (0.65 percent) it has been found to make as good growth as in nonsaline soil.

Unfortunately this grass is often a poor seed producer, since the heads are frequently diseased with ergot. The percentage of germination of the seeds produced is also low, and the plants are very slow in starting growth, 2 or 3 years being required to get a full stand. Bluestem should always be seeded in mixture with some of the other salt-tolerant grasses here mentioned.

Smooth bromegrass and tall oatgrass rank next to bluestem in their tolerance of salinity. The growth of smooth bromegrass is unhindered where the salinity is moderate (0.5 percent.) In fact, this grass can make excellent growth and seed production where the salinity is medium strong (0.7 percent), and it has been observed to ripen some seed in the presence of very strong salinity (1.5 percent). Tall oatgrass is apparently fully as tolerant as smooth bromegrass, being able to make a fair growth and ripen seed in the presence of strong salinity (1 percent).

These three species, bluestem, smooth bromegress, and tall oatgrass, and probably also slender wheatgrass and crested wheatgrass, can be recommended for land containing not more than 1 percent of salts. Since the first two are rather slow-growing grasses, it will be advantageous to seed them in mixture with grasses that grow more rapidly, such as tall oatgrass.

In the warmer irrigated districts, from Texas to California, Bermuda grass and Rhodes grass are rivaled only by some of the native saltgrasses in their tolerance of salinity. Bermuda grass, an Old World species that has become thoroughly naturalized, is a particularly useful plant in that region for pasturage and lawns.

Rhodes grass, which was introduced into the United States from South Africa, has been grown experimentally on a few rather extensive areas by private individuals during the past 8 or 10 years. The

evidence accumulated by these tests in Arizona and California proves rather conclusively that Rhodes grass will grow on soil having a high concentration of salts better than practically any other grass except the native saltgrasses. It appears to be more tolerant of sodium carbonate than most of the grasses. It has been observed, however, that when Rhodes grass is grown on land containing an excessive quantity of salts, it takes up so much from the soil as to make it unpalatable and even injurious to livestock, causing scouring.

Other grasses which have been tested and found to be adapted to moderately saline land, although somewhat less tolerant than those just mentioned, are meadow fescue, Italian ryegrass, redtop (*Agrostis alba*), orchard grass (*Dactylis glomerata*), and timothy (*Phleum pratense*), their tolerance being in about the order named, beginning with the most tolerant. All of these species should give good results where the salinity is not more than medium, and most of them may succeed in the presence of medium-strong salinity if the salts are pretty evenly distributed throughout the depth of soil reached by the roots of the plants.

Italian ryegrass can be recommended as a lawn grass for moderately saline land; although as it is rather short-lived, it has to be reseeded frequently.

In seeding grasses on saline land care should be taken to insure a seedbed relatively free from salt, either by planting immediately after heavy rains or by flooding before seeding. The small seeds of most of the species have little chance of success where there is a heavy accumulation of salts at the surface of the soil.

Some of the native grasses of the western part of the United States are among the most salt-tolerant plants. The bluestem has already been discussed. The familiar desert saltgrass (*Distichlis stricta*) is found in nearly all localities where saline soils occur, and its presence is usually a reliable indicator that the soil contains at least a medium quantity of salts. It often covers the ground with a dense sod and affords considerable pasturage, although of an inferior quality. Nuttall alkali-grass (*Puccinellia nuttalliana*), a species common in wet saline soil in the Great Basin area, is highly esteemed for hay and pasturage, but much difficulty has been encountered in getting this grass established artificially. Alkali sacaton (*Sporobolus airoides*) is widely distributed in the Western States and is a fairly good forage plant.

LEGUMINOUS FORAGE PLANTS

Plants of the pea family (Leguminosae) are generally sensitive to salinity, as is indicated by the fact that very few species of this large and widely distributed family grow naturally in salty soils. Nevertheless, some of these plants are fairly tolerant and can be grown in land carrying a medium quantity of salts—provided the conditions are otherwise favorable. Unless the topsoil is free from excessive salts at the time of seeding, a greater measure of success is likely to be had with large-seeded species, such as field peas, vetches, and horsebeans, than with small seeds like those of alfalfa and clover. The Leguminosae are very sensitive to sodium carbonate, and their culture should not be attempted in so-called "black alkali" land. Where the soil contains not more than a medium quantity of salts, alfalfa, sweetclover, field peas, horsebeans, and some of the vetches may be grown

with fair success. Where these plants can be grown they will be found beneficial to saline soils if plowed in, since the material thus added not only improves the tilth and increases the supply of humus, which such soils often lack, but also furnishes nitrogen for the use of succeeding crops.

STRAWBERRY CLOVER

This clover is outstanding among leguminous plants in its tolerance of salinity and provides excellent pasturage. It has made a very satisfactory growth where the salt content of the surface soil was more than 2 percent in January. However, at this season the plants were in a dormant condition. Observations and experiments indicate that it is as tolerant of salinity as most of the native or introduced grasses, or even more tolerant. Strawberry clover thrives best in a moist soil, and prolonged periods of drought are often fatal to the stand. In growth habits, strawberry clover is very similar to white clover and when once established spreads very rapidly. Seed is produced abundantly under most conditions under which the plants will grow.

SWEETCLOVER

The white-flowered sweetclover is a common weed in many irrigated districts and often attracts attention because of its luxuriant growth under apparently unfavorable conditions. This plant is much esteemed for pasturage, hay, and silage. Sweetclover is a very efficient nitrogen gatherer and a valuable green-manure crop. It is believed that this plant is more tolerant of salinity than is alfalfa, but the results of experiments indicated that medium salinity (0.5 percent) is about the limit for good germination and the production of a heavy crop of sweetclover. Where this percentage of salts is present in the surface soil it is probably easier to get a stand of sweetclover than of alfalfa. In land having a high water table and in soils containing sodium carbonate sweetclover can be successfully grown where alfalfa will not thrive.[4]

Sourclover (*Melilotus indica*), the annual, yellow-flowered species of sweetclover, is much more common in the Southwest than the white-flowered species. In California and Arizona, where it makes most of its growth in winter, this plant is likely to prove useful as a green-manure crop for medium-saline and weak-saline land.

ALFALFA

As alfalfa is the most extensively grown forage crop in the western United States, its relation to salinity has received more attention than those of any other leguminous plant.

It is difficult to start alfalfa in even moderately saline land if the salts are largely accumulated in the surface soil, but if the alfalfa is seeded just after a heavy rain or irrigation the taproots of the young plants will speedily penetrate to a considerable depth, and by the time evaporation has brought the salts back to the surface the feeding roots may be largely out of reach of the surface accumulations. It is a common experience in the West to see old plants of alfalfa

[4] The salt tolerance of sweetclover is further discussed in Leaflet 23, entitled "Sweetclover."

growing vigorously in the presence of surface accumulations of salts that would absolutely prevent getting a stand. In such cases the greater part of the salts must have risen after the alfalfa was seeded. If a stand can be obtained alfalfa is well adapted to preventing excessive accumulation of salts in the topsoil, owing to the shade constantly afforded by this crop. It has been observed that alfalfa can flourish for years in land where, if the stand is plowed up, the salts quickly accumulate near the surface in such large quantities that grain cannot be successfully grown. In some instances the yields of alfalfa seed are actually increased by the presence in the soil of sufficient salts to check the growth of the plants.

In the germinating and seedling stage alfalfa has given satisfactory results where the salinity of the first 6 inches of the soil was at the lower limit of medium salinity (0.4 percent) and contained no sodium carbonate. Young alfalfa is exceedingly sensitive to this constituent, but Professor Hilgard reported that if only a slight amount of sodium carbonate is present a stand can sometimes be obtained if gypsum or land plaster is sown with the seed.

Alfalfa when once established can endure the upper limit of moderate salinity (0.6 percent) if the salts are mostly sulphates. If chlorides form a large proportion of the soluble matter, the lower limit (0.4 percent) is usually about the limit for a healthy growth. But where the soil is very sandy as little as 0.2 percent of the chloride type of salinity may injure the plants, as the soil solution is more concentrated in a sandy than in a loam or clay loam soil.

VETCH

Hairy vetch seems to be easier to germinate in saline soils than the majority of leguminous plants. This vetch germinated well and produced a fair crop of hay where the sulphate salinity was only medium. Other species, such as purple vetch, will probably be found to do equally well under similar conditions.

HORSEBEAN

The horsebean is extensively grown in the Old World as a forage plant. A large-seeded form (the so-called "broadbean") is a favorite table vegetable in Europe. In the United States the plant is grown only to a limited extent and appears to succeed best as a winter crop in California and as a summer crop in rather elevated regions, such as eastern Wyoming, where the summer is comparatively cool. It appears to be decidedly more tolerant of salinity than the majority of leguminous plants. The large size of the seeds makes it easier to get a stand in saline land than is the case with most plants of this family. As it produces a considerable quantity of vegetable matter, the horsebean is worthy of consideration as a green-manure crop for saline land in localities having a suitable climate. Hot weather soon puts an end to the growth of the plants. In soils where the salinity is of the sulphate type the young plants will tolerate medium-strong salinity. Numerous pods are set where the salinity does not exceed the lower limit of the medium grade (0.4 percent).

FIELD PEAS

The field pea is of some importance as a forage crop in the western United States. In the germinating and seedling stages the upper limit of the weak grade of salinity (0.4 percent) marks about the limit of tolerance for this plant. Where salinity of the sulphate type does not exceed 0.2 percent of the weight of the soil, germination has been observed to take place as readily as in nonsaline soil. Crop production is possible in the presence of a medium quantity of sulphates (0.5 percent), and a good crop can be obtained where the salinity does not exceed 0.4 percent.

SORGHUMS

There is a general and well-founded belief in regions where saline soils occur that the sorghums are among the best-adapted forage plants for this type of land. They lend themselves readily to culture on land that is being reclaimed, since they can endure a great deal of flooding. It is the practice in some parts of the Southwest to seed sorghum at the bottoms of furrows, down which water is run at frequent intervals. This keeps the soil relatively fresh around the roots of the young plants and often permits a stand to be established in land containing too much salt to produce a crop if ordinary methods of planting were followed.

The sorgos or saccharine sorghums, grown largely for their leaves and stalks, are likely to give more satisfactory results on saline land than are the grain sorghums, in which seed production is more important. Amber sorghum can make a fair growth and develop heads in the presence of medium-strong salinity, and a good crop may be expected in the presence of medium salinity provided other conditions are favorable. In the germinating and seedling stage the plants do almost as well in the presence of medium salinity as in nonsaline soil. In fact, no other crop plant with which the writers have experimented has shown so great a degree of tolerance in this stage of growth. Sorghum is also apparently more tolerant of sodium carbonate than are the majority of crop plants.

FOXTAIL MILLET

Foxtail millet (*Setaria italica*) is an excellent crop for moderately saline land. A good crop may be expected where there is not more than medium salinity. The germination of the seeds and the growth of the plants during the seedling stage are not materially hindered by this quantity of salts if there is not too great an accumulation at the surface of the soil. In the presence of medium-strong salinity a fair crop can be produced. One percent of salts in the depth of soil occupied by the roots is probably the extreme limit for seed production, and this quantity is too great for profitable crop production.

PROSO

Proso, sometimes known as broomcorn millet (*Panicum miliaceum*), is also somewhat tolerant of salinity, but as it is grown mainly as a grain crop, it is doubtful whether it is as suitable for such soils as foxtail millet. The yield of straw on saline land also appears to be lighter than in the case of foxtail millet. The results of the writers'

experiments in the field indicate that the upper limit of weak salinity (0.4 percent) is about the limit for a good crop of proso. Growth and seed production were greatly reduced at 0.6 percent.

RAPE AND KALE

Rape and kale, which are extensively used for forage in Europe but are little grown in the western United States, are decidedly tolerant of salts. Dwarf Essex rape makes a fair growth in the presence of medium-strong salinity. Where the salinity does not exceed 0.4 percent, the plants can reach full size. Thousand-headed kale, the forage variety, appears to be at least equally tolerant, making a fair growth in the presence of medium-strong salinity.

The chief objection to these plants as a crop for saline land is the difficulty frequently experienced in getting a stand. They appear to be decidedly more sensitive than the sorghums and foxtail millet while in the germinating and seedling stages. The small and delicate seedlings also have great difficulty in breaking through the crust that forms on the surface of certain types of saline land when allowed to become too dry. Care should therefore be taken in seeding these crops on such land to wash the salt out of the surface soil and to irrigate frequently enough to prevent a hard crust from forming until the plants are sufficiently large to shade the ground. If these precautions are observed, rape and kale are likely to prove useful as green-manure crops for saline soils, which are often deficient in humus.

SALTBUSHES

The saltbushes (species of *Atriplex*), including in the broad sense several annual species of "tumble-weed" habit, are among the most characteristic native plants of the western United States which grow naturally on saline land. In fact, the presence of many of the species is a reliable indicator that the soil contains salts in sufficient quantity to injure the majority of cultivated plants. Saltbushes are of value as an element of the natural pasturage or range in the western United States, as cattle and sheep browse, especially where grass is scarce. It has been found, however, that under certain conditions some of the species may be injurious to sheep. While it has been demonstrated that the North American species can be successfully seeded on moist saline land, it has not been proved that the enterprise would be a profitable one.

Some of the Australian saltbushes have been tested rather extensively by the California Agricultural Experiment Station and were found to be capable of tolerating an excessive quantity of salts, in one case as much as 4 percent in the first 4 feet of the soil. In strongly saline soil the plants take up so much salt that they are unpalatable to livestock. It has not been shown that the value of the crop warrants the expense of getting a stand, and the saltbushes have not been grown by farmers in this country to any important extent. The Australian species will probably succeed only in sections having a mild winter, like California, Arizona, and possibly southern Nevada and parts of New Mexico and Texas.

The value of some of the larger growing saltbushes for making hedges and windbreaks in saline land is discussed on another page.

ROOT CROPS

SUGAR BEETS

Sugar beets are undoubtedly the most salt-tolerant of the important field crops grown in the western United States. But while the plants can endure excessive quantities of salts, it is not profitable to grow them in very strongly saline soils because of the injurious effect of the salts upon the size of the roots and the purity coefficient of the juice. The actual limits for profitable sugar-beet growing must be ascertained in each locality by testing the effect of the prevailing type of salinity upon the composition of the roots.

As a rule, a good stand of sugar beets cannot be expected if the soil around the germinating seeds and the roots of the young seedlings contains more than about 0.5 percent of salts. One-tenth of this amount of sodium carbonate is probably the greatest quantity which will permit a stand being obtained. Experienced beet growers find that a heavy irrigation previous to planting often makes it possible to obtain a stand on saline land on which, without this precaution, beets could not be successfully started. The subsequent return of the salts to the surface of the soil may not injure the plants, since after the seedling stage is past sugar beets are much more tolerant of salinity.

When once established, sugar beets may be expected to produce a good crop of marketable roots where the salinity is not more than medium. Even where the salinity is medium strong or strong, a crop of beets suitable for sugar manufacture can sometimes be grown if favorable moisture conditions are maintained and the soil is not too sandy. A much smaller quantity of sodium carbonate will prevent the growth of a crop, although sugar beets will apparently endure more than will the great majority of crop plants.

The fact that the beet is a cultivated crop recommends it for growing on saline land, since intertillage is one of the most effective methods of keeping the salts from accumulating at the surface of the soil, provided the field is cultivated as soon as possible after every rainfall or irrigation.

MANGELS

The mangel or mangel-wurzel, the forage variety of the beet, has been reported by the California Agricultural Experiment Station as being similar to the sugar beet in tolerance of salinity.

CEREALS

The small grains (wheat, emmer, barley, oats, and rye) cannot be recommended for land of more than weak salinity except when grown as a hay crop. While the plants can grow in the presence of a considerable quantity of salts, the quality of the grain is likely to be inferior, the kernels being small and shriveled. Furthermore, unless the land is plowed immediately after harvest, an accumulation of salts at the surface of the soil is favored, since grain stubble affords little or no protection against evaporation and the baking of the soil surface. The land is thus rendered less fit for succeeding crops. Corn is decidedly sensitive and should not be grown on

saline land. Rice, being able to endure a great deal of flooding, may be used as a reclamation crop in regions having a suitable climate.

Wheat for milling purposes should not be grown on land of more than weak salinity. A good hay crop with a fair yield of grain can be obtained on medium saline land if the soil is a loam or clay loam and the moisture conditions are favorable. If sodium carbonate is present, the limits will, of course, be very much lower.

Emmer appears to have about the same degree of salt tolerance as wheat.

Barley is better able to endure salinity. The crop can be grown on land of medium salinity, although near the upper limit of such salinity it is unlikely that a high quality of grain can be obtained. In loam or clay loam soils, if a favorable moisture content is maintained, barley can be grown as a hay crop even when the salinity is medium strong, provided the salt content of the topsoil at the time of seeding is not higher than medium. The limits in the presence of sodium carbonate are much lower, although barley appears to be decidedly superior to wheat in tolerance of this constituent.

For oats, under ordinary conditions, soil of medium salinity is about the limit for a profitable hay crop and a fair yield of grain. A full crop and high quality of grain cannot be excepted if the salinity exceeds 0.4 percent unless other conditions are exceptionally favorable.

Rye is almost, if not quite, equal to barley in tolerance of salts. A fair crop of grain may be obtained on land of medium salinity. Rye is well adapted for growing as a green-manure crop on saline land, although a good stand cannot be expected if the topsoil at the time of seeding is of more than medium salinity.

Corn is decidedly more sensitive than the small grains and is not to be recommended for saline soils. In Egypt, where extensive areas of such land occur and where the people have long been familiar with this problem, corn is said to fail on land that will produce good crops of rice and cotton. Experiments in the United States indicate that even where the salinity is only weak, a good crop of corn cannot be expected.

Rice is regarded as sensitive to brackish water in Louisiana and Texas, but in Egypt it is one of the principal crops grown on saline land that is being reclaimed by drainage and flooding. A good crop has been observed in that country where the salt content of the soil (mainly sodium chloride) was 1 percent. It does not follow that the rice plant is actually much more tolerant than other cereals, for the frequent flooding of land under reclamation keeps the soil solution relatively dilute provided the irrigation water itself has a low salt content. Experiments conducted by the California Agricultural Experiment Station in Imperial Valley indicate that rice may be of value as a reclamation crop in that section. The Texas Agricultural Experiment Station has pointed out the danger of irrigating rice with water containing much common salt. It has been found difficult to fix a definite limit of safety for the salt content of water for this crop, but it is probably advisable to avoid, when possible, using water containing as much as 0.07 percent (40 grains per gallon) of sodium chloride.

FIBER PLANTS

COTTON

Cotton has become an important crop under irrigation in the Southwest. The plants are decidedly tolerant of salinity, making a fair growth in the presence of the strong grade of salinity where sodium chloride is the principal salt. But the limits for a profitable crop are much lower, since it has been observed that a quantity of salts that is too small appreciably to hinder the growth of the plants has an injurious effect upon the number and size of the bolls and retards their ripening, besides probably impairing the length and fineness of the fiber. The long-staple, Egyptian-type cotton that is grown commercially in Arizona is somewhat more tolerant than the upland type, but so far as present information goes, it would seem inadvisable to grow Egyptian and other superior types of cotton where more than weak salinity of the chloride type occurs.

The Arizona Agricultural Experiment Station has reported that on saline land, cotton suffers less than on normal soils from the disease known variously as bacterial blight, angular leaf spot, and black arm.

Cotton, being intertilled while the plants are young and shading the ground very effectively after the middle of the summer, is a desirable crop for moderately saline land in the southern part of the arid region. It requires less irrigation, especially during the early stages of growth, than most of the summer crops which are grown in that area. It is all the more important, therefore, that thorough cultivation be given, in order to prevent the accumulation of the salts at the surface of the soil.

FLAX

Flax has been observed in unirrigated land in North Dakota to make a fair crop where the salinity of the surface foot of the soil was of the medium grade and sulphate type, and a good crop when this salinity was not over 0.4 percent. The presence of an excessive quantity of salts in the soil below the first foot apparently had no injurious effect.

GARDEN VEGETABLES AND TRUCK CROPS

Only scanty data are available for forming a conclusion as to what garden vegetables are most tolerant of salinity. It is inadvisable in the present state of knowledge to grow any truck crop on a large scale in saline soil. The following suggestions are intended for the farmer whose land contains more or less salts and who desires to grow vegetables in a small way for home use.

Asparagus is generally given the first rank among garden vegetables in tolerance of salinity, and when grown in eastern soils it appears to be actually benefited by the application of common salt (sodium chloride). Medium salinity does not prevent the successful growing of asparagus. Onions are also reported to be adapted to

land of medium salinity. Celery is said to do well in California in soil of weak salinity in which sodium chloride is the principal salt.

Other truck crops which are worthy of trial on land of medium or weak salinity, although little is known about their actual degree of tolerance, are the globe artichoke, the beet, cabbage, cauliflower, eggplant, kale, spinach, and sweetpotato.

Potato plants make a fair growth in a soil of medium salinity, but the tubers produced are too small to be marketable. Where the salinity is very weak, potatoes of good quality can doubtless be produced.

TREES AND SHRUBS

It is extremely difficult to determine the limits of salt tolerance of trees, since, in addition to the quantity and kind of salts, the depth of soil in which they are located must be considered in connection with the different kinds of root systems different species of trees possess. A high water table, which is often associated with the presence of excessive salts, is very injurious to most woody plants.

A method that has been suggested by the California Agricultural Experiment Station for getting trees and shrubs established on saline land is to dig the holes some time in advance of planting, fill them partly with good soil and then with water and, after the water has seeped in, complete the filling with good soil.

FRUIT TREES AND GRAPES

In addition to the points already mentioned, the effect of the salts upon the keeping quality and flavor of the fruit cannot be overlooked in the case of orchard crops. It can only be said in a general way that strongly saline soils should be avoided in planting fruit trees, except the date palm and the pomegranate, which will tolerate considerable quantities of salts. The pear and the fig are also fairly resistant so far as concerns the growth of the trees, but the quality of the fruit suffers if more than a very limited quantity of salts is present.

The various stone fruits (plum, peach, apricot, cherry, etc.) are considered sensitive to salinity. The same is true of the orange, lemon, and other citrus fruits and of the Persian ("English") walnut.

Grapes of the European class (*Vitis vinifera*) may be expected to ripen fruit of good quality, except for raisin making, wherever the quantity of salts present is not sufficient to injure the vines themselves.

ORNAMENTAL AND SHADE TREES

Cottonwoods, so extensively planted along roads and ditches and about houses in the western United States, appear to be fairly tolerant of salinity. Fremont cottonwood (*Populus fremonti*) is said to be the species best adapted to such land. The black locust, honeylocust, Chinese elm, and Russian mulberry are also reported to be suitable for planting on soil containing only a moderate quantity of salts. In portions of the Southwest having a mild winter the list of trees that are likely to succeed in such land can be extended to include the umbrella or Chinaberry tree (*Melia azedarach*), the goldenrain-tree (*Koelreuteria*), the European planetree (*Platanus orientalis*),

the oleander, the Australian beefwoods (species of *Casuarina*), the Washingtonia palm, and the date palm. The Canary Island palm (*Phoenix canariensis*), a near relative of the date palm, is also probably tolerant of salinity. Of the species of eucalyptus which have been tested in California, the desert gum (*Eucalyptus rudis*) and the red gum (*E. rostrata*) appear to be best adapted to saline soils.

HEDGES AND WINDBREAKS

Of the shrubs and small trees suitable for hedges and windbreaks the Russian-olive (*Elaeagnus*) is one of the species that can best endure the presence of a moderate quantity of salts. Golden willow is also probably worth testing in regions having a severe winter. In the Southwest the pomegranate and species of tamarisk, which are decidedly salt tolerant, are excellent hedge plants. One species of tamarisk is hardy as far north as central-western Nevada. Some of the larger growing saltbushes are very tolerant of salinity and make good hedges. *Atriplex breweri* is already in use as a hedge plant in the coast region of California, and *A. lentiformis* is recommended for the purpose in Arizona.

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